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AN UNDESCRIBED TIMBER DECAY OF PITCH PINE[1]

L. O. OVERHOLTS

(WITH PLATES 12 AND 13)

In the vicinity of State College, Pennsylvania, the pitch pines (*Pinus rigida*) are dying rather rapidly, especially in the more open woodlands. Most of these trees are fairly mature and the cause of their death has not been satisfactorily determined. The effects of the pine bark borers are very evident just beneath the bark of the dead trees, but whether or not they are responsible for the injury cannot be stated at present. Within a few months after the trees die, and while they are yet standing, they often become heavily infected with the "blue stain" fungus (*Ceratostomella pilifera*) as evidenced by the extensive bluing of the sap wood. After the dead trees fall they are subject to the attacks of several of the wood-destroying fungi. The most important of these are *Polyporus abietinus* (Dicks.) Fries and *Polyporus amorphus* Fries. In fact, the sporophores of these two species are the only ones that have ever been found on timber decayed in the manner described in this article. The decay produced by *P. abietinus* is well known and abundant on both pine and hemlock wood in this vicinity. It is entirely unlike the decay described here and cannot be considered in this connection. The decay produced by *P. amorphus* has not been studied in pure culture inoculations but the evidence at hand is such as to leave no doubt that the effects here described are due to the mycelium of that fungus.

THE FUNGUS AND ITS IDENTIFICATION

Polyporus amorphus has been considered to be quite rare in this country. Specimens submitted to the New York Botanical

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[1] Read before the Botanical Society of America at the New York meeting, December, 1916. Contribution from the Department of Botany, The Pennsylvania State College, No. 11.

Garden within the past year were reported as the first to be received from America. Through the kindness of Dr. Murrill I have been able to compare my specimens with specimens of European origin communicated by Bresadola, and the two are identical. Mr. C. G. Lloyd of Cincinnati, Ohio, has reported the species from different localities in this country. More recently Long[2] has reported that a fungus identified as *P. amorphus* was found rotting slash of the short-leaf pine in Arkansas. At the writer's request specimens from the Arkansas collections were sent for study. No evidence was found that the fungus is not the species in question, but the sporophores are not well developed and a positive determination of Mr. Long's specimens is impossible at this time. Hitherto it had appeared doubtful if the species had so much of a southern range. Present indications are that when well studied its range will be mostly confined to southern Canada, New England, and the states bordering on the Canadian line.

In the vicinity of State College the species is not rare. Probably its small size and resemblance to related species have often caused it to be overlooked or wrongly determined. In the herbarium of the Pennsylvania State College there are at least six different collections of the species and the writer's herbarium contains half as many more. It is probably a safe statement that at present as many collections are known from Pennsylvania as from all other parts of the United States combined. From this it might appear that the species can be of very little economic importance as a producer of timber decay, but it must be borne in mind that very few localities in the United States have been thoroughly explored in a mycological way. Indeed, if the prevalence of the fungus in the vicinity of State College can be regarded as a criterion of its occurrence in other localities of the same latitude it may even happen that the species is one of the more common ones where different species of pines are native. The fact that the fungus is not confined to the wood of pitch pine adds interest in this connection. One collection has been made from the wood of white pine (*Pinus Strobus*), one from an old stump of table mountain pine (*Pinus pungens*), and one from a log of hemlock (*Tsuga canadensis*). These last three collections were among the first to be made and at that time no special attention was given to the type of decay produced. Consequently, material is yet lacking by means of which a comparison might be made of the characteristics of the decay in the wood of other coniferous species. There is no reason for assuming, however, that any essential difference could be detected.

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[2] Long, W. H. Investigations of the rotting of slash in Arkansas (U. S. Dept. Agr. Bul. 496, p. 8, 1917).

The sporophores of the fungus are in some respects quite variable, yet they can be distinguished with ease after their characters are once known. When well developed the sporophore is sessile, but often it is extensively effused-reflexed and sometimes resupinate. Where the pine log lies flat on the ground the fungus is apt to spread itself over needles and chips of pine that happen to lie adjacent to the log. The color of the pileus is gray due to the covering of a grayish tomentum arranged in narrow concentric zones. The hymenium varies in color from flesh-color to orange or brick-red. According to European authorities it may at times be white or cream-colored, but such colors have been observed only in old weathered specimens of our plants. It is quite probable, however, that the depth of color developed is more or less dependent on the abundance of light. At times, and especially when growing over chips and needles of pine, an abundant development of rhizomorphs takes place. These are yellow or light orange in color, cylindric in shape and vary up to almost one millimeter in diameter. The fungus may be described, as follows:

POLYPORUS AMORPHUS Fries

Pileus coriaceous, sessile, effused-reflexed, or occasionally resupinate, 0–2 × 1–3 × 0.1–0.3 cm.; surface whitish or cinereous, villose-pubescent or tomentose, marked with narrow concentric zones; context white, 1–2 mm. thick; tubes less than 2.5 mm. long, the mouths angular, thin walled, flesh-color to orange or brick-red, averaging 2–4 per mm.; spores allantoid, hyaline, 4–5 × 1–2 μ; cystidia none; hyphae not much branched, 3–5 μ.

On wood of pine (*Pinus rigida, P. Strobus,* and *P. pungens*) or running over chips and needles of pine; rarely on wood of other coniferous trees. Probably confined to the northern United States and southern Canada.

Superficially the fungus bears some resemblance to *Polyporus dichrous* Fries, and sometimes the hymenium is perhaps inclined to be somewhat waxy in consistency, but it does not peel off in a thin smooth layer in fresh specimens and the color is usually not the same. Moreover, *P. dichrous* is confined to the wood of deciduous trees. Immature specimens bear some resemblance to certain species of *Merulius* and one such collection was once referred to a species of that genus, but determinations of such immature material are always to be taken with certain reservations until better material is obtained.

Name Used in Designating This Decay

From the standpoint of convenience and simplicity it would be well to have some common name to apply to the decay caused by each of the wood-rotting fungi. Such names should be based on some conspicuous character of the decay. This feature probably can never be carried out in entirety because of the great similarity among the decays produced by several different fungi. For example, decays produced by *Polyporus versicolor* and a number of related species do not differ conspicuously among themselves nor from the decays produced by three or four of the common pileate species of *Stereum*. But the idea should be carried out so far as possible.

Because of the peculiar appearance of the rotted wood it is proposed to designate the decay caused by *Polyporus amorphus* as the "stringy rot" of pitch pine.

Macroscopic Characters of the Decayed Wood

While observations are not complete, the fungus has so far been found attacking only the sapwood of the fallen pines. It has never been found on standing trunks and attempts at locating the mycelium in the sound heart wood have so far failed. Where it attacks the smaller branches in which heart wood has not been formed, it, of course, penetrates entirely through the wood.

As the pine logs lie on the ground one can never judge, even by tapping with a hammer, to what extent the wood is decayed. The outer layers of the sapwood usually form a firm but thin shell made up of wood that is apparently nearly sound. This is probably because these layers have too low a water content for the growth of the fungus. That this surmise is correct is borne out by the fact that where the thick bark of the pitch pine remains as a protective covering on the trunk the outer layers of sapwood are decayed to a considerable extent. The bark falls off rather readily in the pitch pine, especially if the tree stands for several months after it dies. Consequently, in cases where the decay is well advanced the bark is generally lacking and the more sound shell of sapwood is present.

The sound dried sapwood of *Pinus rigida* is of a very light color and contrasts strongly with the brownish red color of the less extensive heartwood. One of the conspicuous characteristics of the decay is the change in color of the diseased sapwood from the normal light color to a shade that matches exactly the "cinnamon buff" of Ridgway's color manual. Since those decays in which delignification of the woody elements takes place result in a whitening of the diseased wood, it can be conjectured at once that the action in this case is at least in part not one of delignification but one in which cellulose is one of the chief elements dissolved.

The most conspicuous feature of the decay is now to be described. When a mass of the decayed wood is examined and attention directed to a lateral view of a rough radial section one sees very narrow bands of fairly firm wood between which the woody elements have been almost entirely removed. In other words, narrow bands of sounder wood alternate with long narrow cavities, neither band nor cavity with a thickness of more than one millimeter. Into these cavities or furrows project small bits of wood, often triangular in outline. The frequency of their occurrence and their form suggest that they are medullary rays. Under the microscope they are seen to be composed mostly of vertical tracheids bound together by the remains of the ray tracheids. The parenchyma cells of the rays have disappeared and the vertical tracheids are well filled with mycelium and are seen to be in a state verging on collapse.

The alternating elongated cavities and bands of wood are the characteristic marks of the decay and have suggested the name "stringy rot." As will be brought out later, the bands of wood remaining are the areas of summer wood, which probably because of its compactness is not so easily destroyed. The elongated cavities represent the spring wood that is destroyed long before the summer wood disappears. It is evident that this separation of spring and summer wood results in the formation of concentric rings in the wood. These rings do not coincide entirely with the annual rings but the annual rings are split into their two growth areas, spring and summer wood. Consequently it is often possible to separate blocks of rotted wood into concentric slabs, although the persistence of groups of vertical tracheids bound together by ray tracheids aids in holding these concentric rings together.

In addition to the above characteristics, the rotted wood may be described as soft and watery in texture when found in the woods. It is quite flexible and readily separates into narrow strings or strands when twisted, often giving a rough broom-like appearance. When dry the well rotted wood is brittle and snaps under slight pressure. No concentric or other cracks due to shrinkage are present as are found in some rots (e. g., that caused by *Polyporus sulphureus, P. borealis,* etc.) Neither are sheets of mycelium ever developed in the cavities that appear. In rare cases small strands of mycelium may appear just under the bark or in the very rotten wood. No spots or colored lines of any sort are present in the decayed wood.

MICROSCOPIC CHARACTERS OF THE DECAYED WOOD

The wood of pitch pine is made up of two elements, i. e., vertical tracheids and medullary rays. The vertical tracheids have a single row of bordered pits on the radial walls. Consequently the radial section alone will show these pits in surface view. When the lignin and cellulose tests[3] are applied to the

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[3] The lignin test found most serviceable was the phloroglucin test with hydrochloric acid. Free hand sections of the wood were first treated with a two per cent. solution of phloroglucin in 95 per cent. alcohol. This was immediately drained off and a drop of rather strong HCl added. The result was a beautiful red color assumed by all lignified membranes.

The best cellulose test was found to be the reaction with chlor-iodide of zinc solution made up as recommended in Steven's Plant Anatomy. If sound wood of *Pinus rigida* the vertical tracheids give the reaction for lignin with the exception of the inner surface of the bordered pits. These remain practically uncolored in the center but most of them show a narrow ring of red at the outer margin. In sections showing the structure of the tracheid walls the middle lamella, secondary lamella, and tertiary or inner lamella all give a lignin reaction that varies in intensity in the different parts. Consequently there is little free cellulose in the vertical tracheids. The medullary rays of the sound wood of pitch pine are bordered above and below with one or more series of horizontal ray tracheids with inner walls conspicuously denticulate as is characteristic of the pitch pine group. These give a definite lignin reaction and do not respond to the cellulose test. The ray parenchyma cells, on the other hand, soon develop the characteristic lavender-violet color when treated with chlor-iodide-zinc solution. Consequently they are composed of unmodified cellulose. These reactions of the sound wood serve as a basis of comparison for detecting changes in the wood decayed by the fungus.

When the wood becomes infected with the mycelium of the fungus the medullary rays are first attacked. The ray parenchyma cells disappear rapidly as can be readily seen either in tangential or radial sections of the wood. The cells that still persist in the angles of the rays as seen in tangential section are ray tracheid cells. Their lignified nature enables them to withstand the attacks of the mycelium for a somewhat longer time. Undoubtedly the rot progresses rapidly inward along the line of the medullary rays. In radial section these hyphae can readily be traced within the cavity formerly occupied by the ray cells and are seen to send off frequent branches into and between the vertical tracheids of the spring wood. The intercellular hyphae enter the tracheids either through the bordered pits or apparently by simply dissolving a hole through the wall, as many such irregular holes can be seen and how they could otherwise originate is not plain. As the hyphae pass through the bordered pits these rapidly become disorganized and many different

cellulose is present it becomes a bluish-lavender color in this solution. Usually the reaction is slow in appearing and increases to a maximum intensity in a very few minutes. The sulphuric acid-iodine test was also used but found much less satisfactory.

stages in their dissolution are readily found in radial section. They are represented in plate 13, figure 3. The disintegration takes place in a more or less centrifugal direction but evidence of dissolution in the outer ring of the border is evident before the more central parts are entirely destroyed.

After entering the tracheids, growth takes place in a vertical direction and so the mycelium rapidly reaches hitherto unattacked medullary rays. At such points one to several hyphal branches are given off to the medullary rays or, as seen in plate 13, figure 1, the main hypha may enter the ray and pass through and out on the opposite side, following the same vertical direction as before but in another line of vertical tracheids. In this manner it is not impossible to trace the hyphae for rather long distances in a vertical direction.

In the meantime the rays first attacked have been practically all destroyed. Soon after the ray parenchyma cells disappear the ray tracheids show evidences of disintegration. Their complete dissolution usually occurs about the time the bordered pits in the vertical tracheids of the near vicinity are being disintegrated. In many cases, however, their lateral walls persist much longer and apparently result in binding together a small bundle of tracheids. These bundles may persist even after the spring wood of a given annual ring has been destroyed so that they project into the resulting cavity and are quite conspicuous, as mentioned under the description of the macroscopic appearance of the decayed wood and as shown in plate 12, figure 2 (left).

When a fairly advanced stage of the decay is studied it is seen that the medullary rays have practically entirely disappeared and the vertical tracheids are in a state of collapse. Prior to this time no free cellulose can be detected in these tracheids. In later stages of decay, however, the reaction to the chlor-iodid-zinc solution is distinctly positive and the remains of the tracheid wall as seen in surface view is colored a uniform lavender-violet. This, of course, means that the lignin has been removed from these walls. It probably does not indicate that cellulose destroying enzymes are not present later, else the wood would not eventually be entirely destroyed. On the other hand, it seems justifiable to conclude that the mycelium at practically every stage of its growth produces both types of enzymes but that in the young mycelium more of the cellulose destroying enzyme is produced while in later stages the lignin destroying enzyme is produced in larger quantities.

Eventually the tracheids in the spring wood are entirely destroyed and long narrow cavities are formed in the space it formerly occupied. The summer wood is attacked before the spring wood is destroyed and it may even be possible that mycelium enters it as early as it does the spring wood. But the more compact structure of the former makes it able to withstand the attacks of the fungus for a much longer time. Even after the spring wood is entirely destroyed the summer wood is quite firm, although it has changed to the cinnamon-buff color and has become quite brittle. Because its destruction is such a long drawn out process it may even be doubted whether in a state of nature it is ever entirely destroyed by this fungus. Longer periods of exposure might result in the entrance of other organisms through which the decay would be hastened and eventually completed.

SUMMARY

Polyporus amorphus cannot yet be said to be a common fungus in this country since only a few collections are known. It is probable, however, that it is more common than these collections would indicate. Indications are that its range will be southern Canada, New England, and the states bordering on the Canadian line.

The fungus causes a characteristic decay of the sapwood of *Pinus rigida,* and has been collected also on wood of *P. Strobus, P. pungens,* and *Tsuga canadensis.*

In external appearance the decayed wood is darker in color than sound wood and is of a cinnamon-buff color (Ridgway). The spring wood is completely decayed long before the summer wood disappears. This results in the formation of concentric cavities alternating with the bands of firmer summer wood, and has suggested the name "stringy rot."

Microscopic examination and microchemical tests establish the fact that the fungus first dissolves out the cellulose of medullary rays, then the bordered pits. The lignified structures including the ray tracheids and the vertical tracheids are then attacked and eventually (at least in the spring wood) entirely destroyed. Consequently it is believed that cellulose dissolving enzymes are produced in quantity by the younger mycelium, although probably a lignin dissolving enzyme is not entirely absent. In later stages of decay a lignin dissolving enzyme is produced in greater quantities.

STATE COLLEGE, PA.

EXPLANATION OF PLATES

PLATE 12

Fig. 1. Sporophores of *Polyporus amorphus* showing its effused-reflexed habit and the concentrically zoned pileus.

Fig. 2. Wood of pitch pine decayed by *Polyporus amorphus*. The elongated cavities alternating with bands of the sounder summer wood are quite conspicuous.

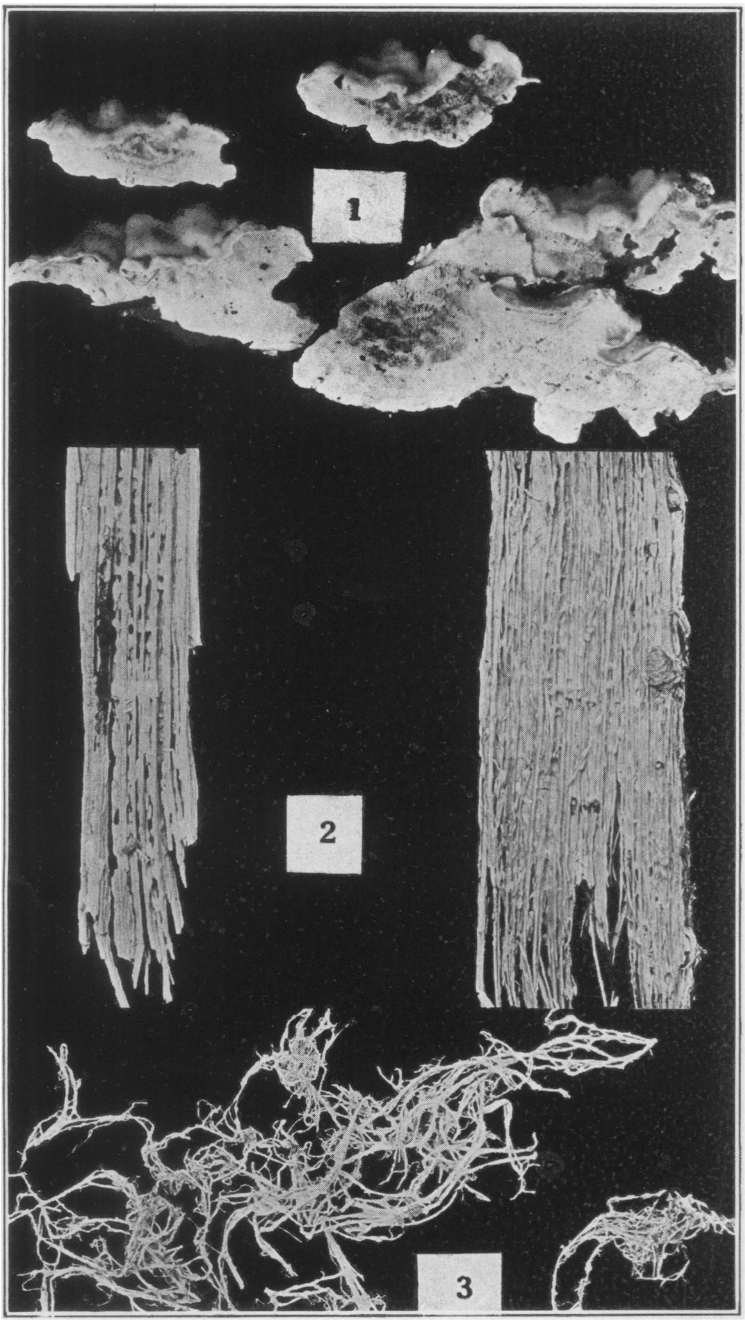
Fig. 3. Rhizomorphs of *Polyporus amorphus*.

PLATE 13

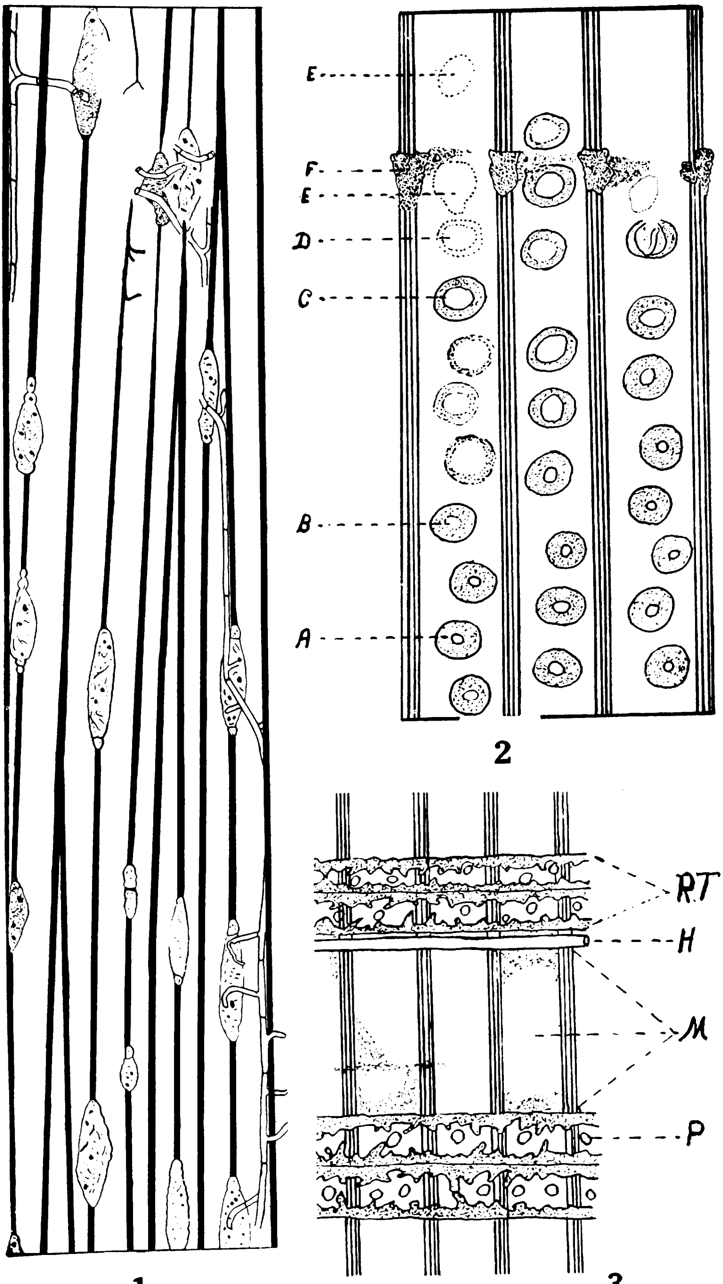
Fig. 1. Camera lucida drawing of a tangential section of pitch pine wood rotted by *Polyporus amorphus*. The parenchyma cells of the medullary rays have entirely disappeared. Ray tracheid cells still persist in the angles of some of the rays. The branching of the hyphae at the rays is conspicuous.

Fig. 2. Camera lucida drawing of a radial section of wood rotted by *Polyporus amorphus*. Various stages in the destruction of the bordered pits are seen at *A–E*. At *F* note remains of a medullary ray.

Fig. 3. Drawing of a radial section of wood rotted by *Polyporus amorphus*. Earlier stage of decay than figure 2. The parenchyma cells have disappeared from between the ray tracheids (R. T.), leaving the cavity *M*. The tracheids still show the characteristic denticulate wall of pitch pines. *P* is a pit in the wall of a ray tracheid. *H*, a large hypha running through the medullary ray.



POLYPORUS AMORPHUS FRIES



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